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A Probabilistic Risk Assessment For Emergency Preparedness

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1. Introduction

In 2011, the Great East Japan Earthquake of magnitude 9.0 and thus Tsunami occurred in Fukushima. Japanese officials assessed the accident as Level 7, the maximum scale value, on the International Nuclear Event Scale. As a result of the accident, a large amount of radioactive material has been released from the containment vessels and the emergency planning zone was set up around the power plant. The importance of nuclear power plant PSA has grown up all over the world due to this incident.

The main concern of this study is to develop a methodology to carry on an emergency preparedness evaluation and to set an exclusive area, or the emergency response area boundary in order to apply it to domestic reference plants. This study also focuses on evaluating the risk parameter of major nuclides through a sensitivity analysis and a safety assessment by calculating the population dose, early fatality, and cancer fatality rates.

2. Methods

2.1 Procedures

The PSA process includes an assessment on the accident mitigate measures in on-site after a nuclear plant accident and evaluates core damage as well as containment failures in the event of radiological release from containment. NUREG-1935, "SOARCA (State-of-the-Art Reactor Consequence Analyses) process", is about scenario selection and estimating radioactive source by using structural analysis with MAAP code analysis. We find out about the off-site consequences in emergency conditions by performing this source term of MACCS2 code as input value. In the off-site analysis, consequences under the emergency condition, is simulated by using MACCS2 code based on the amount of radioactivity released from the result of structural failures. In MACCS2, emergency preparedness is considered; this can be sensitively analyzed by changing emergency response elements. Emergency preparedness plan also can be more efficiently established by evaluating and analyzing the consequences as shown in Fig.1 [1].

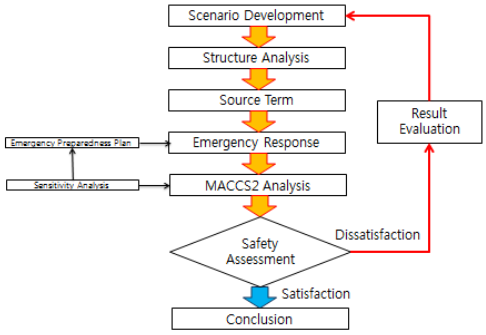

Fig.1. An evaluation methodology and procedure.

2.2 Source Terms

Source Terms are the releasing radioactive substances caused by the severe accident, and the amount of emission is determined by factors such as the initial event types, modes of core damage, and containment failure types. A total of 19 accident scenarios as shown in Fig. 2, are analyzed to create a Source Term Category for the reference plants. They are differentiated and categorized into groups according to similar physical and chemical characteristics; each accident being considered exclusive [2].

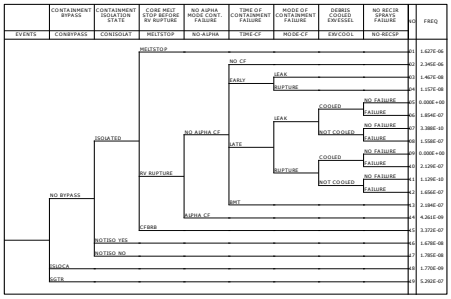

Fig.2. The Source Term Diagram.

2.3 Boundary Analysis for Emergency Response Area

The 100 mSv is one of the major constraints of the effective dose. It is considered as the maximum value to be received for workers in emergency situations. The value is related to preventing serious injury, preventing catastrophic circumstances, and for public evacuation. The regulatory organization considers that the dose rising towards the value justifies protective measures [3,4]. Based on the result of the preceding MACC2 code, a location associated with a value of 100 mSv can

be obtained. An intensity of radioactivity is inversely proportional to the square of the distance. Thus, when the distance increases, the population dose is drastically reduced. It is assumed that an amount of radiation is linear between each interval because the spatial distance data of MACCS2 code is sufficiently large. The boundary is calculated using these assumptions.

2.4 Risk Assessment

The norm and basis for the safety assessment of a nuclear power plant is based on the safety goals of early fatality risk (<5*10^{-7}/RY) and cancer fatality risk (<2*10^{-6}/RY) which are established by the USNRC. Using the Level 3 PSA, a safety assessment of an accident scenario of a plant can be carried out. In addition, according to the General Design Criteria (GDC), when a severe accident takes place, the average release frequency of the dose exceeding 10 mSv within the exclusion area boundary (EAB) of 560m is stipulated to be below 10^{-6}/RY. This is one of the baselines of Level 3 PSA and a safety assessment can be conducted by finding out the Complementary Cumulative Distribution Function (CCDF) of the accident scenario of the reference nuclear power plant as shown in Fig. 3 [5].

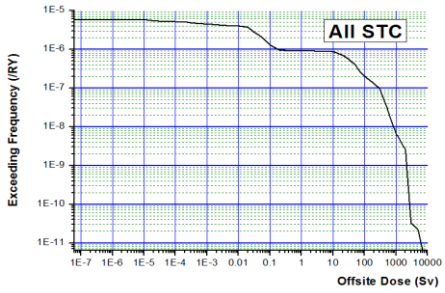

Fig.3. The CCDF of the EAB of the reference plant.

2.5 Risk Parameters

Iodine and Cesium are two major nuclides that have a great influence on human health. By obtaining the dose parameter through a sensitivity analysis on the release fraction of these two nuclides as shown in Fig.4 and Fig. 5, it is possible to assess how much a specific nuclide affects the public health directly. This method allows one to evaluate the nuclide's release, dose, and characteristics related to health effects.

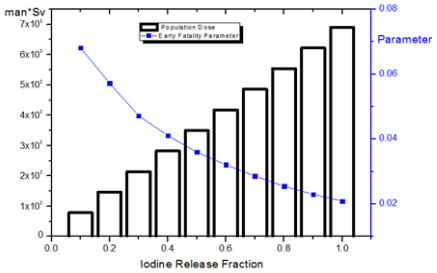

Fig.4. Parameters associated with Early Fatality for the radioactive nuclides, I.

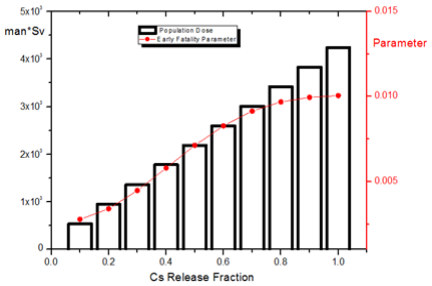

Fig.5. Parameters associated with Early Fatality for the radioactive nuclides, Cs.

3. Conclusions

A methodology for an emergency preparedness, which can be applied to evaluate the damage of the radioactive release as well as to assess the safety of the accident scenario of a nuclear power plant, has been developed and applied for the reference plants in Korea. By applying a source term analysis, an exclusive zone based on the radioactive dose is obtained. And the results of the health effect assessment based on the release fraction of specific nuclides to public with an effective emergency response activity have been simulated. A methodology utilizing the Level 3 PSA with the actual emergency response activities has been developed and applied to typical nuclear accident situations. The plausible standard for performing an emergency plan is suggested and the valuable information regarding emergency preparedness has been produced in this study. For further works, the sensitivity study on important parameters will be performed to simulate the actual severe accident situations such as sheltering, evacuation, and emergency response activities.

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